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Influence of a football match on landing biomechanics and jump performance in female football players

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Abstract
This study aimed to assess the acute effect of a competitive football match on jump performance and kinematic parameters during jump landing in semiprofessional female football players. Twenty-two semiprofessional players (20 ± 3 years) underwent a drop jump task for a posterior video analysis of the landing phase. These measurements were obtained at (1) baseline, (2) after, and (3) 48 h after a competitive football match. A one-way ANOVA with repeated measures was employed to detect differences over the time. There was a main effect of time for maximal knee flexion angle during drop landing ($p = 0.001$). In comparison with baseline, maximal knee flexion angle was reduced immediately post-match and was still reduced 48 h after the match (63.4 ± 8.6 vs 57.0 ± 11.7 vs 48.9 ± 19.1, $p \leq 0.038$). There was also a main effect of time for drop jump height ($p < 0.001$). Drop jump height was reduced immediately post-match and remained low 48 h after the match in comparison with baseline (27.3 ± 3.6 vs 24.5 ± 2.8 ~ 25.5 ± 3.0 cm, $p \leq 0.002$). There was a main effect of time on hip flexion angle during landing ($p = 0.001$), but the pairwise comparison revealed that this variable was not affected immediately post-match but was lower 48 h after the match than at baseline (50.1 ± 10.1 ~ 50.8 ± 13.2 vs 38.1 ± 17.8 °, $p \leq 0.005$). A competitive football match worsened jump performance and several landing biomechanical parameters in female football players, which were still decreased in comparison with baseline even 48 h after the match.

KEYWORDS
fatigue, knee injury, landing, match competition, soccer

1 | INTRODUCTION

The number of women football players has boosted worldwide over the last decade[1] along with an increase in the competitive demands of the game, particularly at the professional level.[2,3] In high-performance football teams, players are exposed to intense physical demands in matches and training during a year-long congested calendar that includes national and international matches. In this scenario, recovery between matches has become particularly relevant to avoid players' overloading as it may impair physical performance and increase injury risk.[4] In this sense, the development of acute and chronic neuromuscular fatigue has been suggested as one of the modifiable risk factors that predispose players to suffer injury,[5,6] especially an anterior cruciate ligament (ACL) tear.[7] Thus, implementing effective preventive strategies that include the control of players' fatigue during and after matches may help to minimize the risk of injury during football match play.[8,9]

In this regard, it has been observed that neuromuscular fatigue may promote alterations in patterns of lower limb muscle activation and induce negative changes in the kinematics and kinetics of the hip, knee, and ankle.[10] These alterations may increase the stress on the ACL during potentially dangerous football movements like cutting or landing. Specifically, previous studies have shown that excessive dynamic knee valgus[11] and decreased knee flexion,[12] reduced ankle dorsiflexion,[13] and higher ground reaction forces[11] may all increase the risk for ACL ruptures during these types of tasks.

Since both changes in kinematic parameters and neuromuscular fatigue have been suggested to be ACL risk factors,[7,10] the next step is to describe the impact of competition on the kinematic parameters related to this injury risk. An accessible evaluation tool is the use of video analysis during landing. The use of video analysis may offer an excellent scenario to determine how fatigue may affect several parameters that have been suggested as risk factors for ACL. However, previous investigations have employed protocols to induce fatigue (i.e., squat exercise at 60% of one repetition maximum until failure) that do not represent the fatigue experienced by football players during match play.[10] Therefore, it is necessary to assess the physical demands of a competitive match and the possible changes in movement patterns involved.

Another accessible assessment tool is the use of biomechanical error assessment scales. For example, Padua et al.[14] proposed a field-based assessment of the biomechanical errors attained during drop landing, the Landing Error Scoring System (LESS). The LESS is a valid, reproducible, and low-cost clinical assessment to detect the presence of multiple high-risk movement patterns associated with ACL injuries. The LESS assesses nine landing concepts and has 17 questions with a continuous 19-point scale. Padua et al.[15] found that five points (or higher) is an optimal cutoff for detecting athletes at higher risk of ACL injury. Additionally, these authors suggested that a change of ±1 point in the LESS score is clinically meaningful and associated with moderate to large biomechanical differences during landing. To the best of the authors' knowledge, only one study[16] has quantified the acute effect of a football match on landing biomechanics, measured by LESS. These authors found that the football match disrupted landing biomechanics, reflected by a higher LESS score. However, the sample in Arslan's et al.[16] study was composed of only male professional football players. Therefore, the current study aimed to assess the acute effect of a competitive football match on kinematics parameters during jump landing in female football players.

2 | METHODS

2.1 | Participants

Twenty-two female semiprofessional football players from two squads volunteered to participate in this investigation (age: 20 ± 3 years, height: 163.3 ± 7.0 cm, weight: 60.6 ± 8.9 kg). The inclusion criteria included: (a) regular participation in the training sessions of the football team (>90%); (b) no history of lower limb pain within the previous 3 months; (c) participation of >70 min in a competitive football match with the team. Exclusion criteria included: (a) knee injuries in the last year or previous history of ACL injury; (b) taking dietary supplements or pain-relieving medications. In the sample, there were eight defenders, nine midfielders, and five forwards. Goalkeepers were not included in the study due to the different nature of their activity during matches.[17] Players trained for an average of 4.02 ± 0.05 h per week across the season and performed roughly one competitive match per week. Before the start of this investigation, all players were familiarized with the testing procedures and signed informed consent prior to the investigation. This investigation was performed in accordance with the latest version of the Declaration of Helsinki 2013 and was approved by the Ethics Review Committee of the University (code: DCD.JLE.01.20).

2.2 | Experimental design

The present research is a descriptive and longitudinal study designed to assess the acute effect of a competitive football match on kinematic and performance variables during drop jump landing in female football players. The matches at which the measurements were performed were always official and played on an artificial turf surface during the same season period (between January and March of 2022). The assessments were performed in three different moments: (a) at baseline, obtained the day before the match, (b) immediately post-match and, (c) 48 h post-match, measured 2 days after the match with no training session in-between. At each of these time points, participants underwent a drop jump task for a posterior video analysis of the landing phase. The video recordings were collected by a sports scientist trained in camera placement with more than 3 years of experience in the recording of videos for jumping tasks. Subsequently, another researcher with 4 years of experience in video analysis of jumping tasks performed the analysis as detailed below. The person responsible for recording and exporting the videos was different from the person who analyzed them to allow a blinded analysis of the videos with respect to the time of collection (i.e., baseline, immediately post-match, 48 h post-match).

Before each testing session, football players performed a standardized 8-min warm-up consisting of running exercises (running straight ahead, running hip out, running hip in, running circling partner, running shoulder contact, and running quick forwards and backwards), based on a previous investigation.[18] Additionally, players completed 2 sets of 6-s neuromuscular activation exercises (base rotations, side to side over the line, and 2-inch runs in place) to complete the warm-up, as previously suggested.[19] In addition, anthropometric measurements, training, and injury histories were collected from players to certify the inclusion/exclusion criteria.

2.3 | Measurements

2.3.1 | Landing Error Scoring System during the drop jump

The drop jump test was performed based on Padua et al.[14] Participants stood on a 30-cm height bench with a nonslip surface, placed halfway up each participant's height from an 80-cm square that was designated as the landing zone. For this measurement, the athlete stepped off and dropped onto the landing zone, absorbing the drop and immediately propelling back up into a maximal height jump. Four days prior to the onset of the experiment, all football players performed a familiarization session that consisted of completing at least two attempts of the drop jump with correct execution and similar height. A valid attempt of the drop jump task was considered as a repetition with no bounce or double jump on the bench followed by a jump that was as high as possible after landing. In addition, trials were excluded and repeated if one of the participants had jumped vertically high off the bench or landed outside of the landing zone. Two smartphones were placed 345 cm apart on the left side (iPhone® 7, Apple Inc.) and in the front side (iPhone® 12, Apple Inc.) of the landing zone at a height of 60 cm. Smartphones were set to record videos in slow-motion mode at 240 fps. The frontal and sagittal videos were analyzed according to the items of the LESS. Specifically, LESS contains 15 questions rated as Yes = 0 or No = 1, plus two questions rated as 0, 1, and 2 depending on the joint displacement and overall performance. A higher LESS score indicates poorer landing technique in landing after a jump; a lower LESS score indicates better landing technique.[14] The diagnostic capacity values of this test were published by Padua et al.[15] expressed as mean [95% CI]. The sensitivity was 0.86 [0.42–0.99], and the specificity was 0.64 [0.62–0.67]. The reliability scores were revised by Hanzlíková et al.[20] showing good-to-excellent intrarater (ICC ranged from 0.82 to 0.99), interrater (ICC ranged from 0.83 to 0.92), and intersession (ICC = 0.81) reliabilities.

2.3.2 | 2D video analysis during the drop jump

The digital video of each drop jump was uploaded to Kinovea 0.9.5 software for conversion to still images. The Kinovea software enabled the measurements in the frontal plane (trunk lateral flexion, knee medial displacement, and stance width) and the sagittal plane (trunk, hip, knee, and ankle position at first contact and angle during the drop jump). The medial displacement of the knee in the frontal plane was measured as the displacement (in cm) of the visually estimated center of the dominant and nondominant knee at two different times in the landing phase (at initial contact and at the point when the player reached maximal knee flexion during the ground contact phase). Lateral trunk flexion in the frontal plane was measured at first contact during the initial landing as the angle formed by a straight line perpendicular to the ground and a straight line connecting the estimated center of the two anterior superior iliac spines to the projection of the spine. The stance width was recorded at first contact by measuring the distance (in cm) between both estimated toe centers. Sagittal ankle, knee, hip, and trunk flexion were quantified in their respective planes from initial contact with the ground to the maximum knee flexion angle during landing, as previously suggested.[21] The ankle flexion angle was defined as the estimated angle formed between the lateral femoral condyle and the lateral malleolus line and a line between the lateral malleolus and the fifth metatarsal head. The knee flexion angle was taken as the estimated angle formed by the straight lines of the thigh and leg segments connecting the greater trochanter, the lateral femoral epicondyle, and the lateral malleolus. The hip flexion angle was described as the estimated angle formed by a straight line joining the greater trochanter and the lateral femoral epicondyle and the straight line connecting the greater trochanter to the lateral projection of the trunk. The trunk flexion angle was defined as the angle formed by the estimated center of both clavicles and the line perpendicular to the ground. The criterion-related validity of knee alignment and hip, knee, trunk, and ankle flexion was recently reviewed by Ruiz-Pérez et al.[21] and these authors recommend measuring knee medial displacement and knee flexion angle as a valid and workable alternative to their respective 3D criteria for quantifying knee motion during drop jumps. In addition, other authors reviewed the agreement between 2D and 3D measures reporting good-to-excellent agreement values for trunk flexion, lateral trunk lean, peak knee flexion, and knee flexion angle[22,23] underlining the potential utility of this valid and low-cost screening tool. Furthermore, previous literature reported substantial-to-almost perfect interrater agreement between researchers who received training in scoring knee and hip control even in real-time observations.[24] However, significant systematic bias was reported for this tool, especially for sagittal plane hip and ankle motion, and caution is needed when interpreting this measure.[21]

2.3.3 | Jump performance

The "MyJump2" app included in *My Jump Lab* was used for analyzing the drop jump and to calculate jump height, contact time, reactive strength index, and stiffness. The jump height was calculated from the flight time using the equation: $h = t^2 \times g/8$,[25] where h is the height in meters, g is the absolute value of gravity in m/s^2, and t is the flight time in seconds.[26] Note that this method to calculate jump height is valid but not as accurate as the impulse-momentum method to calculate the jump height using a platform force. Contact time was defined as the time between the first frame where the initial contact of one foot was visually observed until the take-off frame of both feet during the first landing. The reactive strength index was calculated by dividing jump height by contact time.[27] Leg stiffness was described as the vertical movement of the center of mass during landing and is estimated based on Morin et al.,[28] considering leg length (great trochanter to ground distance in a standing position) and 90° squat length to the ground (great trochanter to ground distance in a 90° squat position). Jump height has shown to be a highly valid and reliable measure of both intra- and intersession in female athletes based on the flight time method of calculation when compared to a contact platform.[26]

2.3.4 | Competitive match

The external match load during each competitive match was recorded by the GPS units (Wimu ProTM, RealTrack Systems) which have shown a good level of accuracy to assess running patterns in official competitions.[29] The GPS devices obtained data with a frequency of 10 Hz. According to the manufacturer's recommendations, all the devices were positioned inside a vest and were activated in the middle of the football pitch 15 min before data collection to allow the acquisition of satellite signals and synchronization of the GPS clock with the satellite's atomic clock. Synchronized bands were also placed on the chest to monitor heart rate. Following each match, data were downloaded to a personal computer and analyzed using a customized software package SPRO™. The studied parameters selected were total running distance covered, high-speed running distance covered at 18–21 km/h, 21–24 km/h, and >24 km/h, explosive distance covered with accelerations $>1.12\,m/s^2$, distance covered with acceleration $>3\,m/s^2$, distance in m covered with decelerations $<-3\,m/s^2$, and mean heart rate.[30]

The rating of perceived exertion (RPE) induced by the match was measured with the Borg CR-10 scale (from very, very easy [1 point] to maximum [10 points]), which was recorded 30 min after the end of the game.[31] The session RPE (s-RPE) was obtained for each player by multiplying the player's RPE by the effective match time (in min) and it is expressed in arbitrary units (AU), as recommended previously.[32]

2.4 | Statistical analysis

Descriptive statistics (mean and standard deviation [SD]) were calculated for all variables measured in this study. The normal distribution and sphericity were analyzed by Shapiro–Wilk test and Mauchly's test, respectively. The Greenhouse–Geisser correction was applied when sphericity was violated. An N-way ANOVA was computed to ensure parity of physical load variables between matches. A one-way repeated-measure analysis of variance (ANOVA) was performed to evaluate the changes in the variables measured during the drop jump task across three different time points (baseline, immediately post-match, and 48 h post-match). Effect size for ANOVA was reported based on partial eta-squared values (η_P^2). If a significant main effect of time was found, post hoc comparisons were carried out subjected to Holm–Bonferroni correction. Effect size (ES) was reported based on Cohen's *d* for post hoc comparisons. Threshold values for effect size of post hoc comparisons were defined as trivial (<0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0), and very large (>2.0).[33] All statistical analysis was performed with Python 3.7 using the open-source library Pingouin v0.3.8.[34]

3 | RESULTS

The average match time was 85.9 ± 8 min, with a mean s-RPE of 649.2 ± 108.1 AU. The total running distance covered by the players during the match was

TABLE 1 Jump height, Landing Error System Scale, Reactive Strength Index, contact time, and stiffness obtained during a drop jump before (baseline), after (immediately post-match), and 48 h after (48 h post-match) an official competitive football match in women football players.

Variable (units)	Baseline mean ± SD	Immediately post-match mean ± SD	48 h post-match mean ± SD	Baseline vs immediately post-match *p*, ES	Baseline vs 48 h post-match *p*, ES	Immediately post-match vs 48 h post-match *p*, ES
Jump height (cm)	27.3 ± 3.6	24.5 ± 2.8	25.5 ± 3.0	<0.001, −0.86	0.002, −0.54	0.098, 0.34
Landing Error System Scale (points)	5.1 ± 2.4	5.5 ± 1.6	4.8 ± 1.7	–	–	–
Reactive Strength Index	0.83 ± 0.14	0.79 ± 0.16	0.78 ± 0.10	–	–	–
Contact time (ms)	579.77 ± 69.78	581.98 ± 99.87	589.50 ± 58.50	–	–	–
Stiffness (kN/m)	3.41 ± 1.17	3.44 ± 1.57	3.19 ± 0.77	–	–	–

Abbreviations: ES, effect size; SD, standard deviation.

10171.9 ± 2247.3 m, high-speed running distance at 18–21 km/h was 185.2 ± 128.4 m (1.8% of the total running distance covered), high-speed running distance at 21–24 km/h was 70.9 ± 82.2 m (0.7% of the total running distance covered), and high-speed running distance at >24 km/h was 33.4 ± 79.6 m (0.3% of the total running distance covered). The explosive distance covered with accelerations >1.12 m/s^2 was 870.6 ± 301.3 m (8.6% of the total running distance covered), and the mean distance covered in accelerating and decelerating >/< ±3 m/s^2 was 183.0 ± 86.2 m (1.8% of the total running distance covered) and 131.1 ± 75.6 m (1.3% of the total running distance covered), respectively. Finally, the mean heart rate and peak heart rate during the match were 157 ± 10 bpm and 193 ± 8 bpm, respectively.

The ANOVA revealed a main effect of time for drop jump height ($\eta_P^2 = 0.38$, $p < 0.001$), with no time effect for LESS ($\eta_P^2 = 0.09$, $p = 0.145$), reactive strength index ($\eta_P^2 = 0.12$, $p = 0.08$), contact time ($\eta_P^2 = 0.01$, $p = 0.757$), and stiffness ($\eta_P^2 = 0.04$, $p = 0.429$). Table 1 shows the mean ± SD for jump performance variables and post hoc comparisons for jump height. Results indicated that jump height decreased immediately post-match by 11.3% (ES = −0.86, $p < 0.001$) from baseline values. Forty-eight hours immediately post-match, jump height was still significantly lower than at baseline by 6.9% (ES = −0.54, $p = 0.002$).

The ANOVA revealed a main effect of time for knee flexion angle at initial contact ($\eta_P^2 = 0.19$, $p = 0.013$), hip flexion angle at initial contact ($\eta_P^2 = 0.19$, $p = 0.028$), hip flexion angle until maximal knee flexion ($\eta_P^2 = 0.30$, $p = 0.001$), maximal knee flexion angle ($\eta_P^2 = 0.29$, $p = 0.001$), nondominant ($\eta_P^2 = 0.21$, $p = 0.014$) and dominant knee medial displacement at initial contact ($\eta_P^2 = 0.20$, $p = 0.010$), trunk flexion angle until maximal knee flexion ($\eta_P^2 = 0.29$, $p = 0.001$), and stance width ($\eta P^2 = 0.46$, $p < 0.001$). However, the ANOVA did not report a main effect of time for trunk flexion angle at initial contact ($\eta_P^2 = 0.10$, $p = 0.144$), ankle plantar flexion angle at initial contact ($\eta_P^2 = 0.11$, $p = 0.093$), ankle dorsiflexion angle until maximal knee flexion ($\eta_P^2 = 0.09$, $p = 0.153$), and lateral trunk flexion angle at initial contact ($\eta_P^2 = 0.08$, $p = 0.180$). Table 2 summarizes the mean ± SD for video analysis variables and post hoc comparisons for variables with a statistically significant effect of time. In comparison with the baseline, the sagittal plane analysis showed a decrease immediately post-match in maximal knee flexion angle by 11.2% (ES = −0.62, $p = 0.038$) and by 29.7% 48 h after the match (ES = −0.98, $p = 0.001$). In addition, 48 h after the match, values in maximal knee flexion angle decreased by 16.6% (ES = −0.51, $p = 0.038$) when compared to immediately post-match values. In contrast, knee flexion angle at initial contact increased 48 h after the match by 15.4% (ES = 0.99, $p = 0.005$) from baseline value. Last, hip flexion angle until maximal knee flexion decreased 48 h post-match by 31.6% (ES = −0.83, $p = 0.001$) from baseline values and decreased by 33.2% (ES = −0.81, $p = 0.005$) from immediately post-match values. In contrast, hip flexion angle at initial contact increased 48 h after the match by 13.8% (ES = 0.73, $p = 0.024$) from baseline. Trunk flexion angle decreased 48 h after the match by 75.1% (ES = −1.21, $p = <0.001$) and by 71.9% (ES = −0.98, $p = 0.002$) respect to baseline and immediately post-match values, respectively.

Frontal plane analysis results revealed an increase in immediately post-match stance width by 14.6% (ES = 0.87, $p = <0.001$) and 48 h after the match by 16.1% (ES = 1.03, $p = <0.001$), respectively, in comparison with baseline. Knee medial displacement at initial contact significantly increased immediately post-match by 2.9 cm (ES = 1.54, $p = 0.012$) in the dominant limb and by 3.3 cm (ES = 0.89, $p = 0.014$) in the nondominant limb from baseline. In addition, knee medial displacement 48 h after the match decreased by 2.1 cm (ES = −0.62, $p = 0.024$) and by 2.1 cm

TABLE 2 Biomechanical landing variables at different planes obtained during a drop jump before (baseline), after (immediately post) and 48 h after (48 h post-match) an official competitive football match in women football players.

Variable (units)	Baseline mean ± SD	Immediately post-match mean ± SD	48 h post-match mean ± SD	Baseline vs immediately post *p*, ES	Baseline vs post 48 h *p*, ES	Immediately post vs 48 h post-match *p*, ES
Sagittal						
Knee flexion angle at initial contact (°)	35.7 ± 6.7	39.1 ± 6.0	42.2 ± 6.4	0.121, 0.54	**0.005, 0.99**	0.155, 0.49
Hip flexion angle at initial contact (°)	62.3 ± 6.9	59.2 ± 7.6	68.7 ± 16.6	0.107, −0.43	0.065, 0.50	**0.024, 0.73**
Trunk flexion angle at initial contact (°)	23.3 ± 5.5	18.4 ± 5.9	25.1 ± 17.7	–	–	–
Ankle plantar flexion angle at initial contact (°)	17.1 ± 16.8	14.1 ± 16.2	7.5 ± 13.6	–	–	–
Maximal knee flexion angle (°)	63.4 ± 8.6	57.0 ± 11.7	48.9 ± 19.1	**0.038, −0.62**	**0.001, −0.98**	**0.038, −0.51**
Hip flexion angle until maximal knee flexion (°)	50.1 ± 10.1	50.8 ± 13.2	38. 1 ± 17.8	0.835, 0.05	**0.001, −0.83**	**0.005, −0.81**
Trunk flexion angle until maximal knee flexion (°)	26.5 ± 9.9	26.0 ± 13.3	15.1 ± 8.9	0.893, −0.04	**<0.001, −1.21**	**0.002, −0.96**
Ankle dorsiflexion angle until maximal knee flexion (°)	30.5 ± 16.3	21.7 ± 24.1	24.62 ± 12.8	–	–	–
Frontal						
Nondominant knee medial displacement (cm)	−0.3 ± 4.1	2.9 ± 3.2	0.8 ± 2.6	**0.014, 0.89**	0.108, 0.34	**0.048, −0.71**
Dominant knee medial displacement (cm)	1.0 ± 3.7	3.96 ± 3.3	1.9 ± 3.4	**0.012, 1.54**	0.341, 0.24	**0.024, −0.62**
Lateral trunk flexion angle at initial contact (°)	2.9 ± 1.0	4.3 ± 2.2	3.9 ± 2.8	–	–	–
Stance width (cm)	29.4 ± 6.0	34.4 ± 5.6	35.0 ± 4.8	**<0.001, 0.87**	**<0.001, 1.03**	0.511, 0.11

Abbreviations: ES, effect size; SD, standard deviation.

The significance level is $p<0.05$.

(ES = −0.71, $p = 0.048$) from immediately post-match measures in the dominant and nondominant limbs, respectively.

4 | DISCUSSION

This study aimed to assess the acute effect of a competitive official football match on kinematics and performance parameters during drop jump landing in semiprofessional female players. The main findings of this investigation indicate that kinematic parameters during a drop jump landing in sagittal (less knee flexion angle) and frontal planes (increase in knee medial displacement and stance width at initial contact) were disrupted after the match. Furthermore, the data reflected that the disruption in some landing parameters was still present 48 h after the competitive match in kinematic variables of the knee joint (increase in knee flexion angle at initial contact but less maximal angle in sagittal plane), hip joint (increase in flexion angle at initial contact but less angle until maximal knee flexion), trunk (less flexion angle until maximal knee flexion), and feet (increase in stance width). In addition, performance during a drop jump decreased after the football match (jump height was reduced) and remained reduced 48 h after the match (jump height was still reduced). Collectively, all this information suggests that a competitive football match worsened jump performance and several landing biomechanical parameters in female football players. Additionally, the regaining of the landing biomechanics and jump performance 48 h after the competitive football match was incomplete, at least in comparison with pre-match/baseline values. This indicates that baseline performance during jumping and landing in a drop task needs more than 48 h of recovery.

Although the relationship between the kinematic changes during landing reported here and the risk of ACL injury is not direct,[35,36] the results of this study suggest that the fatigue produced by a competitive match on female football players may be a potential contributing factor associated, theoretically at least, with the development of increased stress on the ACL during landing.[7,11,12] For example, the knee sagittal flexion angle may be related to a higher stiffness during landing, which could be considered as a potentially negative factor for ACL injury.[37] However, the authors do not recommend utilizing knee frontal plane measurements as kinematic indicators after a match because it has been recently found no association of these parameters as risk factors in a prospective cohort of 722 non-injured and 56 noncontact ACL-injured female elite handball and football players.[36] Thus, the authors suggest that the measurement of hip and knee sagittal flexion angle (particularly knee flexion angle due to the measurement properties previously reported against 3D criteria[21]) during the landing of a drop jump could serve as more appropriate parameters of control during subsequent training sessions after a match to value the regain of landing biomechanics.

Furthermore, our study revealed that the LESS was not sensitive enough to detect statistically significant differences in landing parameters after the match. Although this scoring system has been suggested as a valid and reliable tool to identify potentially high-risk movement patterns during a jump-landing task,[20] our data indicate that, at least with the fatigue developed with an official match, this score was unable to detect any change between baseline and immediately post-match measurements. In addition, the mean difference found after the match with respect to baseline measurement was not clinically meaningful because it was less than 1 unit, a value lower than the minimum detectable change suggested by Padua et al.[15] Our results were in line with those of a previous study[38] conducted with 110 female collegiate athletes, indicating that, although some landing errors may be present after sports competition, these may not entail a clinically relevant variation in LESS. However, our results differ from those shown by Arslan et al.,[16] who analyzed the effect of a competitive match on landing biomechanics in male professional football players. Arslan et al.[16] found that the football match induced a lower LESS score, reflecting that football match play disrupted landing biomechanics. However, these authors did not present values of the variables that produced a lower LESS, and it is difficult to understand which landing parameters were negatively affected by the football match.

Jump height during a CMJ is one of the most common valid indicators used to evaluate football match-related fatigue. Previous studies have reported significant decreases in CMJ height even 72 h after a football match in women.[39] The present results are not directly comparable with these previous studies because the height reached and the characteristics of the drop jump are substantially different to a CMJ. However, the data of jump height of the current study reflect the presence of fatigue after the match, which is not resolved within 48 h of recovery, as previously found with CMJ.[39] Although not measured in this study, potential mechanisms explaining reductions in jump height may be associated with alterations in the structure of muscle fibers,[40] among other factors.

As a practical application of these results, trainers, coaches and medical staff should control the training load during the 2 days after a football match to avoid exposing unrecovered players to high load levels, which potentially may predispose them to increased ACL stress.

4.1 | Limitations

This study has some limitations that should be discussed to understand the true utility of the experiment. First, only external load (i.e., locomotive parameters) and internal load (i.e., s-RPE and heart rate) derived only from an official match were examined. It is possible that external loads incurred during the training days prior to the match or the chronic fatigue accumulated through the season also contributed to the state of fatigue present after the match. Although the influence of these variables was minimal in the outcomes of this study as they were present in both pre- and post-match measurements, future investigations should determine the effect of chronic exposure induced by repeated football matches across the season on landing biomechanics and jump performance. Second, in the current study, there was no training session set after the match and before the measurement 48 h after the match. Hence, it is not possible to determine if the use of a recovery-based training session the day after the match is useful to accelerate the regain of jump performance and landing parameters. Third, the methods and tools described in the methodology are reachable for most football practitioners, but their use requires proper training and precision in the placement of the cameras and video analysis, as these factors can clearly impact the validity and reliability of the measurements. In addition, the LESS, jump performance assessment with MyJump2 app and 2D video kinematic assessments are partly subjective and carry a certain risk of bias (i.e., when selecting the frame or estimating the center of a given joint). In this sense, only one "time-blinded" evaluator was responsible of the video analysis to ensure that the same criteria were respected in all measurements. Therefore, it is necessary to be cautious with the outcomes generated through these tools when interpreting and implementing them in a practical context. Finally, we were unable to assess joint moments due to the experimental setup and tools employed. Despite these methodological limitations, we considered that the outcomes of this study are of interest to strength and conditioning coaches and other football practitioners, particularly to the ones working in female squads, because the measurements are easy to obtain and applicable to the context of most professional football teams. In any case, future research should consider further kinetic measures during drop landing and verify how the management of the training load after the match influences the pace of recovery. In addition, future investigations should record and control other variables that may contribute to the time course of recovery of jump performance and landing biomechanics (i.e., sleep time, post-match nutrition and hydration, etc.).

5 | PERSPECTIVE

The present study included measurements of drop jump performance and landing biomechanics just after the end of an official football and 48 h after in semiprofessional female football players. The data of this study indicate that the fatigue induced by the football match worsened several landing biomechanical parameters which were still impaired 48 h after the match. These results indicate that female football players did not resolve the fatiguing effect of the football match on jump performance and some landing biomechanical parameters even after 48 h of recovery. From a practical perspective, knee flexion angle and hip flexion angle until maximal knee flexion, as well as jump height, may serve as indicators to monitor recovery following a competitive match in female football players.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Research data are not shared.

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